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China Report

SCIENCE AND TECHNOLOGY

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JPRS-CST-84-001

16 January 1984

CHINA REPORT

SCIENCE AND TECHNOLOGY

CONTENTS

NATIONAL DEVELOPMENTS

PRC TO IMPORT MORE TECHNOLOGY, SAY PLANNERS

OW110210 Beijing XINHUA in English 0151 GMT 11 Dec 83

[Text] Beijing, 11 December (XINHUA)--China will continue importing advanced technology to speed completion of major economic projects and transformation of existing enterprises, XINHUA learned from organizations in charge of technology import.

They stressed the country's long-term commitment to technology imports, ranging from energy development to large-scale integrated circuits.

China has so far imported technology from the United States, Western Europe, Japan and other countries for major projects under construction. The projects include the key manufacturing technology of two 300,000-kilowatt thermal power generating units in Anhui and Shandong Provinces and a 500,000-voltage power transforming and transmission line between Taiyuan and Beijing.

China is also planning to import technologies for making optical fibers, large-scale integrated circuits and compound fertilizers, and prospecting and exploiting offshore oil as well as saving energy in the metallurgical industry.

Special priority will be given to the import of machine-building, electronics and material technology to help pave the way for upgrading the country's old enterprises and founding new ones built with advanced equipment.

There are now 380,000 enterprises in China. The Chinese Government has decided to construct 890 major projects, 400 of which are to be completed before the end of 1985.

Attention will also be paid to the import of technologies for tapping energy resources, reducing consumption of energy and raw materials, developing mining and new products, and improving quality of consumer goods.

Market surveys show that more than several hundred thousand refrigerators will be required next year to meet consumer demands. However, China could produce only several dozen thousand refrigerator compressors annually, and plans are underway to import technology for building two large compressor factories in Beijing and Guangzhou.

China will also increase import of technologies to speed up the renovation of existing enterprises. Pilot practices of such efforts are now underway in Shanghai and Tianjin while many other cities, provinces and autonomous regions and industrial ministries have also begun drafting technical transformation programs.

Since 1978, China has gradually shifted its policies from the import of complete plants to the introduction of new technology in various forms. Further plans are being drawn up to encourage foreign technology transfers, including reduction or remission of custom duties and some categories of taxes on imported instruments and equipment attached to imported technology by small and medium-sized enterprises.

CSO: 4010/23

NATIONAL DEVELOPMENTS

EDITORIAL ON SCIENTIFIC, TECHNOLOGICAL PROGRESS

SK150838 Jinan DAZHONG RIBAO in Chinese 29 Nov 83 p 1

[Editorial: "To Vigorously Promote Industry, We Must Depend on Scientific and Technological Progress"]

[Excerpts] To develop modernization and promote the economy, we must depend on scientific and technological progress. This is a basic guiding ideology for economic construction. Vigoriously improving the scientific and technological work of industrial and communications enterprises and promoting technological progress have an extremely important significance not only from a current point of view but also from a long-term point of view. This issue should be brought to the great attention of leading comrades at all levels of industrial departments and the vast number of workers and staff members.

At present, our province's industrial technology is far from meeting the serious upcoming challenges. In terms of products, the quality is poor, the variety is limited, and the level is low. In view of technological equipment, the technological level is backward, the equipment is obsolete, and the technical performance is poor. Insofar as the ranks of workers and staff members are concerned, the cultural level is low, the number of technicians is small, and the quality of their technology is poor. Because our province's industrial technology is a low level, the economic results are poor and our products lack competitive capability and the ability to meeting an emergency, quite a few products cannot enter foreign markets, some cannot be sold at markets outside the province, and some even cannot hold their ground at the markets within the province and face the danger of being elbowed out of the markets.

Worse still, many comrades lack understanding of the backwardness in industrial technology. Some regard scientific and technological work as a soft task and think that "distant water cannot quench a present thirst." Therefore, they fail to place the scientific and technological work in its due position. Some are accustomed to the old managerial methods for work and to the outmoded production forms, are satisfied with the present technological level, the available designs and variety of products, and with the already attained technological standards, and lack the sense of urgency in promoting technological progress. Such spiritual situations as sticking to old ways, following the beaten party, and being unrealistically complacent have hampered the further development of the scientific and technological work.

The 12th Party Congress has explicitly pointed out that the key to the four modernizations lies in the modernization of science and technology and science and technology should be regarded as the strategic priority of economic development. Raising the scientific and technological work to such a high plane by the CPC Central Committee is determined by the position and role of science and technology in developing the four modernizations. Therefore, all industrial departments and enterprises should fully understand the important role of technical progress, find out where they fall short in line with the advanced foreign and domestic levels, strengthen their sense of responsibility and urgency in promoting technological progress, actually regard the scientific and technological work as a strategic task, and concentrate their energy on the technological progress. Herein lies the key to raising economic results of enterprises and to meeting the new challenges.

CSO: 4008/87

NATIONAL DEVELOPMENTS

RENMIN RIBAO SUPPORTS TECHNOLOGICAL PROGRESS

HK140811 Beijing RENMIN RIBAO in Chinese 7 Dec 83 p 1

[Editorial: "Technological Progress Is the Only Way to Invigorate the Economy"]

[Text] The urgent task of invigorating our national economy, speeding up the building of the four modernizations, and filling the economic and technological gaps between our country and economically developed countries is to have a world view, act in a down-to-earth manner, grasp well technological achievements, and carry out technological reform in our operating industries and enterprises, all of which has become more and more common.

One of the outstanding problems in our operating industries and enterprises is poor economic results. This is mainly evident in poor performance and product quality, and a high consumption of energy resources and raw materials. Though the output value of many enterprises has increased, most values are exaggerated and the wealth they actually create for the society is less than specified. Some enterprises even produce products which are unsalable and overstocked. They not only do not create wealth for the society but also waste precious energy resources and raw material for no reason. Some enterprises have brought about losses to and become a secret worry of the state as their products' performance and quality are poor.

Poor performance and product qaulity and the high consumption of energy resources and raw material are caused by many reasons, such as having weak and slack leading groups, a low standard of administrative and management levels, irrational labor organizations, lax labor discipline, and so forth. When we began to implement all-round consolidation in enterprises early last year, our aim was to solve these problems. Many enterprises have been changed and their economic results improved after consolidation. However, an enterprise must rely on scientific and technological progress and take the road of technological advances if it is to fundamentally improve the performance and quality of products and to reduce the consumption of energy resources and raw materials.

The promotion of technological progress is a major decision made after consideration from a strategic, high level of economic development. We must unify our understanding, pool our wisdom, and strengthen various sectors, and conscientiously do well this major task. In the past 30 years, world science and technology have been developing rapidly and new technology and new industries

are emerging in an endless stream. Renewal of production equipment and transformation of production countries. Among all kinds of reasons for their economic growth, the proportion for their reliance on technological progress is above 60 percent. Over a long period in the past, our country stressed the construction of new factories (which was necessary during the period of laying a foundation for industrialization) and the expansion of the scale of enterprises for expanding reproduction at the expense of technological remolding and technological progress among the existing enterprises. Therefore, the technological equipment of most of the existing enterprises is rather backward and many products are "the same as decades ago." For example, only about 10 percent of the machinery plants' products attain the standard of the 1970's or the early 1980's, and still less are of a quality at the top of the world. If we do not spend much effort to grasp the work of technological progress and develop new technological and industrial departments by all possible means as soon as possible, the gap between our country and economically developed countries will become greater and greater. Regarding this problem, the sooner we can take initiative.

In order to promote technological progress, we must proceed from the foundation of unified planning. The plan for the next few years should regard the improvement of the performance and quality of products and the low consumption. This is because, if a product is unmarketable or has practical meaning even though its consumption can be reduced further. At present, we must first improve the quality of products which we are still producing, and work hard to improve the rate of high quality products. At the same time, we must make great efforts to explore new territory and develop new products. For technological progress among the existing enterprises, we should regard their "products" as the "head of a dragon," and adopt various kinds of technological measures, such as tackling technological problems, exploiting, popularizing, importing, and reforming technology, an so on, in accordance with the need to "improve this generation of products, develop a new generation of products, and still develop a further new generation of products in advance." In addition, we should apply the systematized engineering method and carry out the work of various sectors "in a coordinated way."

In order to bring into full play the role of science and technology in the national economy and to transform science and technology in the national economy and to transform science and technology as, powerful productive forces, we must grasp well the work of popularizing and applying the scientific and technological achievements, in particular, we must organize well the "four transformations," that is, transformation of advanced technology from laboratory to factories, from military use to domestic use, from coastal area to inland, and from overseas to domestic use. In the work of popularizing technology, we must first consider the integration of those projects which require that the location of production, mass and large-scale production, and ripe technology be within easy reach. In popularizing work, we must place the focal point on the advanced technology which will improve the quality of both products of projects, develop variety, save energy, reduce the consumption of raw materials, improve the environment, and so forth. We must pay attention to the application of small electronic computers as they are widely used overseas. Judging from the field of production, computers can be used in managing enterprise, controlling the production process, reforming technology, and so on.

Some of our enterprises have already begun to use computers and they have made very obvious results.

We must speed up our pace of exploiting and importing technology. Regarding these issues, we must pay attention to both advances in technology and the rationality in economics, and must have foresight and sagacity while proceeding from reality. For example, it is impossible for us to demand that all adopt the latest technology and pursue automation one-sidedly for a rather long period of time in the future due to insufficient capital despite abundant manpower and the natural resources in our country, but we may skip stages of some traditional industrial development in some fields as we started rather late. We may directly exploit and utilize the new technology and form our new productive forces. In other words, we must take our own way rather than creeping up behind somebody. Our principle is: Keep the initiative in our own hands, widely adopt the strong points of others, and merge and refine them, so as to form our unique style.

In order to promote technological progress, we must have strong and powerful scientific and technological ranks as well as strong and powerful ranks to utilize scientific and technological results. Therefore, in the work of promoting technological progress in enterprises, we must give prominence to the training of staff and workers, and up-dating technological and administrative personnel. We must not grudge money and time spent on practice, and adopt various measures to solve this problem well.

To devote much effort in promoting technological progress in enterprises is an important condition for greeting the new invigorated economy. If we cannot do this work well, we will make mistakes in strategy, and this will greatly and adversely affect the progress of socialist modernization. Department heads, governors, mayors, directors, bureau chiefs, managers and factory heads must grasp this work personally, and work hard to study new scientific and technological knowledge. Technological progress is the focal point of the work of core enterprises in key trades and key cities. They must devote much more effort in this respect. We believe that as long as we all start the work from a higher level to a lower level, and work hard unremittingly, a new situation will certainly be created in the existing enterprises, economic results will certainly be improved remarkably, and we shall have high hopes for attaining a vigorous and prosperous national economy.

CSO: 4008/87

MEASUREMENT OF INFRASONIC WAVES FROM REMOTELY DETONATED ARTIFICIAL EXPLOSION

Beijing SHENGXUE XUEBAO [ACTA ACUSTICA] in Chinese Vol 8 No 2, Mar 83
pp 118-121

[Article by Tu Yan [1458 3596] and Liu Hongqi [0491 3163 3825]]

[Text] I. Preface

Infrasonic waves generated by earthquakes or strong artificial explosions are difficult to measure, and very few systematic observations of such waves have been made. Therefore, it is of considerable interest to accumulate data on infrasonic waves produced by artificial explosions or earthquakes in order to study their characteristics, production mechanism, and the laws of propagation through the atmosphere.

In this article, the measured results and data processing methods of infrasonic waves originated from a remotely detonated, 10,000-ton explosion are presented. First, the characteristics of the moving coil infrasonic detection system, and the measurement techniques and results are described; next, the analysis results of the recorded infrasonic wavetrains using digital correlation techniques are presented; finally, the acoustic pressure, obtained by analyzing and processing the infrasonic signals, and its average spectrum, calculated using the method of fast Fourier transform with Hamming window are reported.

II. The Infrasonic Measuring Equipment, Methods and Results

The infrasonic wave generated by a remotely detonated strong explosion is detected by a moving coil detection system. The acoustic signal received by the removing coil infrasonic microphone is converted into electric signal and transmitted to a long-period detector, where it is amplified using the principle of optical leverage. By using a tracking recorder to follow the moving light spot reflected from the lens of the detector, the received signal can be recorded on a long strip chart.

In order to eliminate the short-period wind interference and the long-period interference due to atmospheric disturbances, and to enhance the signal to noise ratio of the received signal, the acoustic microphone is designed to have sharp attenuation in the short-period and long-period region outside the

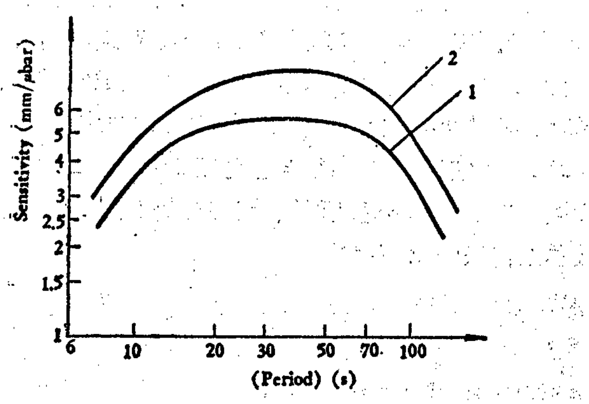

Figure 1. The Response of Detection System by Infrasonic Waves

pass band. The response of the detection system is shown in Fig. 1, where the abscissa denotes period in seconds, and the ordinate denotes sensitivity expressed in terms of the number of millimeters of strip chart per microbar of acoustic pressure.

The infrasonic array consists of two infrasonic microphones separated by 3,853.3 meters; the angle between the normal to the line connecting the two microphones and the direction of explosion is 17.26 degrees, and the distance between the source of the explosion and microphone 2 is 301 km. The infrasonic signals received by the two microphones are recorded on the same chart. The schematic diagram of the infrasonic array and the direction of explosion is shown in Fig. 2.

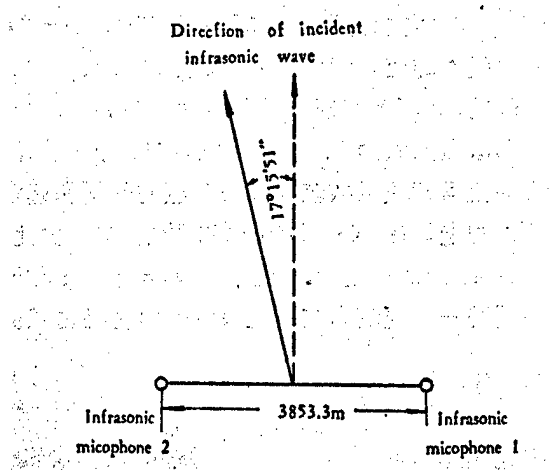

Figure 2. The Infrasonic Detection Array

The wavetrains of the infrasonic signals recorded by microphone 1 and 2 are presented in Fig. 3. At the time of recording there was considerable interference caused by a force-2 surface wind. To facilitate the identification of infrasonic waves, the wavetrains recorded at detection points 1 and 2 were shifted in time by 3.4 seconds, as shown in Fig. 4. The time reference indicated on the chart corresponds to detection point 2; the relative time

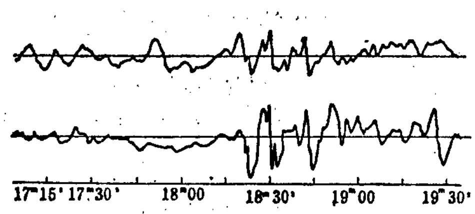

Figure 3. The Diagram of Infrasonic Records

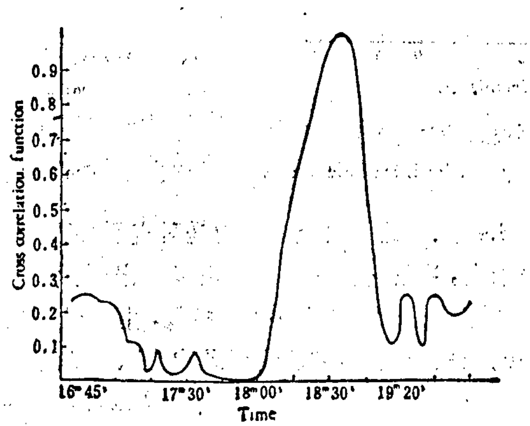

Figure 4. The Cross Correlation Function as a Function of Time

reference of detection point 1 is defonated by an arrow with an explanatory note beside it. It can be seen from the chart that in the time interval between 1800 and 1900, the recorded wavetrains at detection points 1 and 2 are similar. Since the magnitude of wind interference is much smaller than the sound signal, the high degree of correlation between the wavetrains recorded approximately 3 km apart indicates that it is an infrasonic signal.

III. Correlation Analysis of the Data and Results

In order to characterize the infrasonic signals quantitatively, correlation techniques are used to analyze the wavetrains recorded at the two detection points, and to compute the correlation coefficients by recursion with respect to time. The first step is to digitize the recorded infrasonic wavetrains; the digitized and sampled data are detonated by $f_1(\Delta\ell)$ and $f_2(\Delta\ell)$ respectively, where Δ is the sampling interval, and ℓ is the sample number. If τ is the time delay between the data received at detection point 2 relative to point 1; N is the total number of sample points for each group in the calculation of the cross correlation function, m is the recursive number of each group; and i is the index number of each group, then the correlation coefficient $R_{12}(i, \tau)$ is given by the following expression:

$$R_{12}(i,\tau) = \frac{1}{N}\sum_{l=1+m,i}^{N+m,i} [f_1(\Delta l) - \overline{f_1(\Delta l)}] \cdot [f_2(\Delta l - \tau) - \overline{f_2(\Delta l)}] \qquad (1)$$

$$i = 1, 2, 3 \cdots$$

By computing the cross correlation coefficients $R_{12}(i, \tau)$ for each value of i in equation (1), one can determine the variation of signal correlation coefficient with time.

For the present calculation, the sample points are separated by 0.375 seconds, and N is equal to 100. By varying the value of time delay τ of the main signal band, one can determine the maximum value of the cross correlation coefficient $R_{12}(i, \tau)$, and the corresponding time delay τ_0, which in this case is equal to 3.4 seconds. Based on this value of τ, the time variation of the correlation function is then calculated, as shown in Fig. 4. The ordinate in this figure is $R_{12}(i, \tau)/R_{\max 12}(i,\tau)$, which has a maximum value of 1. It can be seen from the figure that the correlation coefficient is quite large in the interval between 18 min 5 sec and 18 min 50 sec. By subtracting the time of explosion from the time of peak correlation, one can deduce that the time required for the main signal to travel from the center of explosion to the detection point 1 is between 1,087 seconds and 1,132 seconds. It follows that the corresponding group velocity is between 266.4 m/sec and 276.9 m/sec, which is in good agreement with the theoretical calculation of group velocity of soundwaves propagating in the atmosphere. This result provides additional evidence that the recorded signal is indeed an infrasonic signal transmitted from the source of explosion.

IV. Spectrum Analysis of the Signal

This section presents an analysis of the acoustic pressure and average spectrum of an infrasonic wave generated by a remotely detonated explosion.

The acoustic pressure of the infrasonic wave can be calculated by first measuring the amplitude of the main signal band from the recorded wavetrain, and then determining the pressure peak of the infrasonic signal using the response curve of the detection system. The peak value is calculated to be 6.7 μbar.

In addition, spectrum analysis is also performed on the primary portion of the infrasonic signal using the method of Fourier transform.

To eliminate the effect of sidelobes, a Hamming window is used in the calculation, as follows:

$$Q(T) = \sum_{l=1}^{M} [f(\Delta l) W(T) e^{-\frac{2\pi i \Delta \cdot l}{T}}] \Delta \qquad (2)$$

where the Hamming window function is given by:

$$W(T) = 0.54 - 0.46 \left(\frac{2\pi l \cdot \Delta}{T}\right) \qquad (3)$$

T is the period of the spectrum in seconds, and M is the total number of samples.

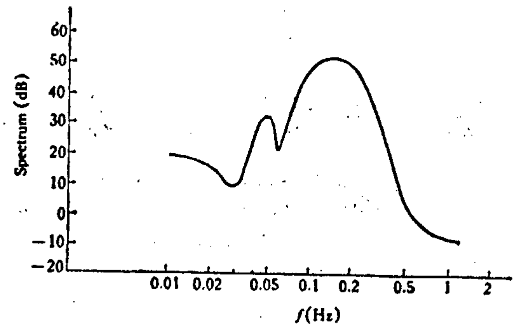

Figure 5. The Average Spectrum Signals

A computer program based on the method of fast Fourier transform is implemented on a microcomputer to calculate the spectrum of the relative sound pressure. The spectrum of the infrasonic signal is presented in Fig. 5. It can be seen that the infrasonic signal generated by the explosion exists over a range extending from 2 to 30 seconds; the main frequency band is between 3-15 seconds.

This article describes the measurement method and results of infrasonic waves generated by the violent motion of the earth surface caused by a large explosion. It has been demonstrated that this measurement technique and equipment can be used to measure infrasonic waves produced by earthquakes; it has also been demonstrated that a near-surface shallow earthquake can produce infrasonic waves over a large distance.

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CSO: 4008/5

THEORETICAL AND OBSERVED DISPERSION OF ACOUSTIC-GRAVITY WAVES IN ATMOSPHERE

Beijing XHENGXUE XUEBAO [ACTA ACUSTICA] in Chinese Vol 8 No 4, Jul 83
pp 227-235

[Article by Tu Yan [1458 3596]]

[Text] I. Preface

Infrasonic waves can propagate over a long distance in the atmosphere. Due to the effects of atmospheric wave guide, propagation of infrasonic waves is subject to frequency dispersion, and the received wavetrain after propagating several thousand kilometers becomes quite complicated. In fact, the opportunity of conducting an infrasonic propagation experiment is very limited. In order to understand the dispersion characteristics of infrasonic waves propagating in the atmosphere, theoretical calculations and effective use of experimental data have become important topics in the study of infrasonic waves generated by a strong explosion.

Theoretical studies of the dispersion characteristics of acoustic-gravity waves propagating in the atmosphere have been performed by many researchers; Pekeries[1,2] used a simple atmospheric model to calculate frequency dispersion; Yamamoto[3,4] used a model of stratosphere and thermosphere to calculate the dispersion of infrasonic waves produced by nuclear explosions. Later, the effects of atmospheric temperature variation with altitude on infrasonic dispersion have been studied by Hunt,[5] Weston,[6] Pfeffer,[7-9] Press and Harkrider.[10] But experimental results[11] show that the distribution of wind with altitude has a significant effect on infrasonic propagation.

In this article, the equation of infrasonic wave motion in a moving medium is derived, taking into account the effects of gravity; also, the equations of frequency dispersion are expressed in terms of divergence of velocity, using a stratified atmospheric model. The frequency dispersion characteristics of acoustics-gravity waves are computed using a more realistic multilayer atmospheric model. Numerical results show that both the phase velocity and group velocity have two components: acoustic component and gravitational component. The dispersion of the acoustic component is more sensitive to wind. Generally, the short period group velocites in the downwind and upwind directions can differ by more than 10 percent. The gravitational velocity in certain atmospheric models is further divided into several components with different dispersion characteristics. This result is in good agreement with the observed

frequency dispersion characteristics of infrasonic waves produced by a nuclear explosion. This phenomenon is illustrated by actual examples in the article.

II. Equations of Infrasonic Wave Motion in a Moving Medium With Gravitational Effects

After propagating over a long distance, the primary period of infrasonic wave produced by a large explosion ranges from several seconds to several hundred seconds; the corresponding wavelength can reach more than tens of kilometers. Within a distance comparable to the wavelength, the density of the medium may vary considerably, and it will differ from the ambient density due to effects of compression and expansion by the infrasonic wave. For this reason the effect of gravity must be taken into consideration.

The equation of wave motion is derived by treating the atmosphere as a uniform medium and by making the following assumptions: considering the medium as an ideal gas; neglecting the effects of viscosity, heat conduction, and turbulence; adiabatic motion; and taking into account no other external forces except gravity. Under these assumptions, the pressure P, density ρ, entropy S, and velocity **U** of the medium can each be expressed as the sum of a value under its equilibrium state and a perturbed value under the action of the acoustic wave. The equilibrium-state value is denoted by the subscript "0," and the perturbed value is denoted by the subscript "1." Also, the gravitational acceleration is denoted by g and the gas constant is denoted by R. Then, from the equations of aerodynamics, the first order equations of state, continuity, and the equations of conservation of momentum and energy are given by equations (1-4) respectively:

$$P_0 = \rho_0 R T_0 \tag{1}$$

$$\frac{\partial \rho_1}{\partial t} + \boldsymbol{U}_0 \cdot \nabla \rho_1 + \boldsymbol{U}_1 \cdot \nabla \rho_0 + \rho_0 \nabla \cdot \boldsymbol{U}_1 = 0 \tag{2}$$

$$\rho_0 \frac{\partial \boldsymbol{U}_1}{\partial t} + \rho_0 (\boldsymbol{U}_1 \cdot \nabla) \boldsymbol{U}_0 + \rho_0 (\boldsymbol{U}_0 \cdot \nabla) \boldsymbol{U}_1 + \nabla P_1 + \rho_1 g \nabla \psi = 0 \tag{3}$$

$$\frac{\partial P_1}{\partial t} + \boldsymbol{U}_0 \cdot \nabla P_1 + \boldsymbol{U}_1 \cdot \nabla P_0 = c^2 \left(\frac{\partial \rho_1}{\partial t} + \boldsymbol{U}_0 \cdot \nabla \rho_1 + \boldsymbol{U}_1 \cdot \nabla \rho_0 \right) = 0 \tag{4}$$

where $\nabla\psi$ is a unit vector in the [0,0,-1] direction, i.e., in the opposite direction to gravity along the z-axis.

Let the horizontal plane be the x-y plane, and let the z-axis be perpendicular to the x-y plane. Assume that the temperature and wind are uniform in the x-y plane and are functions of z; assume also that the wind velocity direction is along the x-axis and its velocity components are given by the following notations: the components of $\mathbf{U}_0$ are $[U_0(z), 0,0]$; the components of $\mathbf{U}_1$ are [u,v,w].

In addition, the atmosphere under the state of equilibrium satisfies the equation:

$$\frac{dP_0}{dz} = -\rho_0 g \tag{5}$$

For convenience let us introduce the following definition of the divergence of perturbed velocity:

$$\chi = \operatorname{div} \boldsymbol{U}_1 = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \tag{6}$$

By substituting equation (6) into equations (1-5) and eliminating ρ_1 one obtains:

$$\rho_0\left(\frac{\partial}{\partial t} + \boldsymbol{U}_0 \cdot \nabla\right)^2 \boldsymbol{U}_1 + \rho_0\left(\frac{\partial}{\partial t} + \boldsymbol{U}_0 \cdot \nabla\right)(\boldsymbol{U}_1 \cdot \nabla)\boldsymbol{U}_0 + \left(\frac{\partial}{\partial t} + \boldsymbol{U}_0 \cdot \nabla\right)\rho_1 g \nabla\phi$$
$$= \nabla(c^2\chi\rho_0) + \nabla(\boldsymbol{U}_1 \cdot \nabla P_0) + (\nabla(\boldsymbol{U}_0 \cdot \nabla))P_1 \tag{7}$$

The vector equation (7) can be written in the form of three scalar equations:

$$\left(\frac{\partial}{\partial t} + U_0\frac{\partial}{\partial x}\right)^2 u = \frac{\partial}{\partial x}\left(c^2\chi + \frac{w\rho_0'}{\rho_0}\right) - \left(\frac{\partial}{\partial t} + U_0\frac{\partial}{\partial x}\right) w U_0' \tag{8}$$

$$\left(\frac{\partial}{\partial t} + U_0\frac{\partial}{\partial x}\right)^2 v = \frac{\partial}{\partial y}\left(c^2\chi + \frac{w\rho_0'}{\rho_0}\right) \tag{9}$$

$$\left(\frac{\partial}{\partial t} + U_0\frac{\partial}{\partial x}\right)^2 w = \frac{\partial}{\partial z}\left(c^2\chi + \frac{w\rho_0'}{\rho_0}\right) + \left[(1-\gamma)g - \frac{dc^2}{dz}\right]\chi$$
$$- U_0'\left[\frac{\partial u}{\partial t} + U_0\frac{\partial u}{\partial x} + U_0' w\right] \tag{10}$$

where the notation " ' " represents derivative with respect to z.

Equations (8-10) can be converted into a set of ordinary equations by applying the Fourier integral transform

$$f_i = e^{-i\omega t}\iint_{-\infty}^{+\infty} e^{i(\alpha x + \beta y)} F_i \, d\alpha \, d\beta \tag{11}$$

where f_i denotes the untransformed quantity and F_i denotes the transformed quantity. α and β are respectively projections of the wave number k on the x and y axes, and ω is the circular frequency.

By introducing the notations Φ, P, μ, ν and Ω to represent the transformed variables of X, p, u, v and w, one obtains the following equations after applying Fourier transforms to equations (8-10) and to equation (6):

$$(-i\omega + i\alpha U_0)^2\mu = i\alpha(c^2\Phi - \Omega g) - (-i\omega + i\alpha U_0)U_0'\Omega \tag{12}$$

$$(-i\omega + i\alpha U_0)^2\nu = i\beta(c^2\Phi - \Omega g) \tag{13}$$

$$(-i\omega + i\alpha U_0)^2\Omega = \frac{\partial}{\partial z}(c^2\Phi - \Omega g) + \left[(1-\gamma)g - \frac{dc^2}{dz}\right]\Phi - U_0'[(-i\omega + i\alpha U_0)\mu + U_0'\Omega] \tag{14}$$

$$\Phi = i\alpha\mu + i\beta\nu + \frac{\partial\Omega}{\partial z} \tag{15}$$

Equations (12-15) contain four unknown quantities μ, ν, Ω and Φ. Eliminating μ, ν and Ω from these equations yields:

$$\begin{aligned} c^2\Phi'' &+ \left[\frac{\partial c^2}{\partial z} - \gamma g + c^2\eta\frac{\partial}{\partial z}\left(\frac{1}{\eta}\right)\right]\Phi' - \left\{\left[\sigma^2 - \frac{k^2}{\sigma^2}\left(g\frac{\partial c^2}{\partial z} + c^2\sigma^2 - (1-\gamma)g^2\right)\right]\right. \\ &+ \frac{\gamma g}{2\sigma^2}\frac{d\sigma^2}{dz} + \frac{1}{2\sigma^2}\frac{\partial}{\partial z}\left(c^2\frac{d\sigma^2}{dz}\right) - \frac{c^2}{4\sigma^4}\left(\frac{d\sigma^2}{dz}\right)^2 \\ &\left. - \left(\gamma g + \frac{gk^2c^2}{\sigma^2} + \frac{c^2}{2\sigma^2}\frac{d\sigma^2}{dz}\right)\frac{1}{\eta}\frac{d\eta}{dz}\right\}\Phi = 0 \end{aligned} \tag{16}$$

where

$$\alpha = k\cos\theta \tag{17}$$

$$\beta = k\sin\theta \tag{18}$$

$$\sigma = -i\omega + i\alpha U_0 \tag{19}$$

$$\eta = \sigma^4 - g^2k^2 \tag{20}$$

and θ is the angle between the direction of propagation and the x-axis.

Equation (16) is the desired equation of wave motion in a moving medium with the effects of gravitational force taken into account.

III. The Equations of Frequency Dispersion of Acoustic-Gravity Waves

The variations of temperature and wind velocity with altitude in an actual atmosphere are too complicated to be represented by simple analytical functions. Therefore, it is not feasible to use analytical methods to obtain solutions which agree with actual propagation phenomena. In this section, frequency dispersion equations expressed in terms of matrices are derived. These equations can be solved numerically to obtain dispersion characteristics which are in good agreement with actual atmospheric conditions.

First, the atmosphere is divided into N horizontal layers; in each layer the temperature and wind velocity are assigned certain values. Then, formulas connecting the layers are established by applying the boundary conditions at the interfaces. Finally, the frequency dispersion equation is obtained by using the boundary conditions of the top and bottom layers to eliminate the unknown coefficients.

Assume that the atmosphere is composed of N layers; within each layer the temperature and wind velocity are assumed to be constant, thus the terms in equation (16) which contain derivatives of c and U with respect to z all vanish. Let all the quantities in the mth layer be denoted by the subscript "m." Equation (16) becomes:

$$c_m^2\Phi_m'' - \gamma g\Phi_m' - \left[\sigma_m^2 + k^2c_m^2 + (\gamma - 1)\frac{g_m^2k^2}{\sigma_m^2}\right]\Phi_m = 0 \tag{21}$$

The Fourier transforms of the z-component of velocity and pressure satisfy the following equations:

$$\eta_m\Omega_m(z) = \sigma_m^2c_m^2\Phi_m' - (g_mc_m^2k^2 + \gamma g_m\sigma_m^2)\Phi_m \tag{22}$$

$$\eta_mP_m(z) = -\sigma_m\rho_m[g_mc_m^2\Phi_m' - (\gamma g_m^2 + \sigma_m^2c_m^2)\Phi_m] \tag{23}$$

Assume that the solution to equation (21) is of the form:

$$\Phi_m = \sum_{j=1,2} A_j\exp(\zeta_mz - i\omega t + i\alpha x + i\beta y) \tag{24}$$

Substituting equation (24) into equation (21) yields

$$c_m^2\zeta_m^2 - \gamma g_m\zeta_m - \left\{\sigma_m^2 + k^2c_m^2 + k^2(\gamma - 1)\frac{g_m^2}{\sigma_m^2}\right\} = 0 \tag{25}$$

Equation (25) has two solutions ζ_{m1} and ζ_{m2} given by:

$$\zeta_{m1,2} = \frac{\gamma g_m}{2c_m^2} \pm \left\{\left(\frac{\gamma g_m}{2c_m^2}\right)^2 + \frac{1}{c_m^2}\left[\sigma_m^2 + k^2c_m^2 + k^2(\gamma - 1)\left(\frac{g_m}{\sigma_m}\right)^2\right]\right\}^{1/2} \tag{26}$$

By substituting equation (26) into equations (22) and (23) and rearranging terms, one obtains:

$$\begin{aligned}\Omega_m(z) = {} & A_1\left[\frac{\sigma_m^2c_m^2\zeta_{m1}}{\eta_m} - (g_mc_m^2k^2 + \gamma g_m\sigma_m^2)/\eta_m\right] \\ & \times \exp[\zeta_{m1}z - i\omega t + i\alpha x + i\beta y] \\ & + A_2\left[\frac{\sigma_m^2c_m^2\zeta_{m2}}{\eta_m} - (g_mc_m^2k^2 + \gamma g_m\sigma_m^2)/\eta_m\right] \\ & \times \exp[\zeta_{m2}z - i\omega t + i\alpha x + i\beta y]\end{aligned} \tag{27}$$

$$\begin{aligned}P_m(z) = {} & A_1\left[\frac{-\sigma_m\rho_{0m}g_mc_m^2}{\eta_m}\zeta_{m1} + \frac{\sigma_m\rho_{0m}}{\eta_m}(\gamma g_m^2 + \sigma_m^2c_m^2)\right]e^{(\zeta_{m1}z - i\omega t + i\alpha x + i\beta y)} \\ & + A_2\left[\frac{-\sigma_m\rho_{0m}g_mc_m^2}{\eta_m}\zeta_{m2} + \frac{\sigma_m\rho_{0m}}{\eta_m}(\gamma g_m^2 + \sigma_m^2c_m^2)\right]e^{(\zeta_{m2}z - i\omega t + i\alpha x + i\beta y)}\end{aligned} \tag{28}$$

To faciliate computation, equations (27) and (28) can be written in matrix form by introducing the notations:

$$(a_m)_{11} = \frac{1}{\eta_m}[\sigma_m^2 c_m^2 \zeta_{m1} - g_m c_m^2 k^2 - \gamma g_m \sigma_m^2] e^{\zeta_{m1} z - i\omega t + i\alpha x + i\beta y} \tag{29}$$

$$(a_m)_{12} = \frac{1}{\eta_m}[\sigma_m^2 c_m^2 \zeta_{m2} - g_m c_m^2 k^2 - \gamma g_m \sigma_m^2] e^{\zeta_{m2} z - i\omega t + i\alpha x + i\beta y} \tag{30}$$

$$(a_m)_{21} = \frac{-\sigma_m \rho_m}{\eta_m}[g_m c_m^2 \zeta_{m1} - (\gamma g_m^2 + \sigma_m^2 c_m^2)] e^{\zeta_{m1} z - i\omega t + i\alpha x + i\beta y} \tag{31}$$

$$(a_m)_{22} = \frac{-\sigma_m \rho_m}{\eta_m}[g_m c_m^2 \zeta_{m2} - (\gamma g_m^2 + \sigma_m^2 c_m^2)] e^{\zeta_{m2} z - i\omega t + i\alpha x + i\beta y} \tag{32}$$

$$\begin{bmatrix} \Omega_{Hm} \\ P_{Hm} \end{bmatrix} = \begin{bmatrix} (a_m)_{H11} & (a_m)_{H12} \\ (a_m)_{H21} & (a_m)_{H22} \end{bmatrix} \begin{bmatrix} A_{H1} \\ H_{H2} \end{bmatrix} \tag{33}$$

$$\begin{bmatrix} \Omega_{Bm} \\ P_{Bm} \end{bmatrix} = \begin{bmatrix} (a_m)_{B11} & (a_m)_{B12} \\ (a_m)_{B21} & (a_m)_{B22} \end{bmatrix} \begin{bmatrix} A_{B1} \\ A_{B2} \end{bmatrix} \tag{34}$$

where the subscripts "H" and "B" are used to denote values corresponding to the top and bottom of each layer respectively.

Eliminating A_1 and A_2 from equations (33) and (34) yields

$$\begin{bmatrix} \Omega_{Hm} \\ P_{Hm} \end{bmatrix} = \begin{bmatrix} (b_m)_{11} & (b_m)_{12} \\ (b_m)_{21} & (b_m)_{22} \end{bmatrix} \begin{bmatrix} \Omega_{Bm} \\ P_{Bm} \end{bmatrix} \tag{35}$$

where

$$(b_m)_{11} = [(a_m)_{H11}(a_m)_{B22} - (a_m)_{H12}(a_m)_{B21}]/|a_{Bm}| \tag{36}$$

$$(b_m)_{12} = [(a_m)_{H12}(a_m)_{B11} - (a_m)_{B12}(a_m)_{H11}]/|a_{Bm}| \tag{37}$$

$$(b_m)_{21} = [(a_m)_{H21}(a_m)_{B22} - (a_m)_{H22}(a_m)_{B21}]/|a_{Bm}| \tag{38}$$

$$(b_m)_{22} = [(a_m)_{H22}(a_m)_{B11} - (a_m)_{H21}(a_m)_{B12}]/|a_{Bm}| \tag{39}$$

and

$$|a_{Bm}| = [(a_m)_{B11}(a_m)_{B22} - (a_m)_{B12}(a_m)_{B21}] \tag{40}$$

Equation (35) defines the relationship between the parameters at the top and bottom of each layer.

The relationship between parameters of two adjacent layers is established by applying boundary conditions. Let d_m be the thickness of the mth layer, h be the incremental height at the top of the layer. The conditions at the interface of two adjacent layers are:

$$\Omega_{m+1}(h) = \Omega_m(d_m + h) \tag{41}$$

$$P_{0m+1}(h) = P_{0m}(d_m + h) + g_m[\rho_{m+1}(h) - \rho_m(d_m + h)]\frac{i}{\omega}\Omega_m(h) \tag{42}$$

If one further introduces the definition

$$\Delta\rho_m = \rho_{Hm} - \rho_{B(m+1)} \tag{43}$$

then equation (42) becomes:

$$P_{0(m+1)} = P_{0m}(d_m + h) + i\,\frac{\rho_m \Delta \rho_m}{\omega}\,\Omega_m(h) \tag{44}$$

The above boundary conditions can be written in matrix form to provide the relationship between parameters at the top of the mth layer and parameters at the bottom of the $(m + 1)$th layer:

$$\begin{bmatrix} \Omega_{B(m+1)} \\ P_{B(m+1)} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \dfrac{i g_m \Delta \rho_m}{\omega} & 1 \end{bmatrix} \begin{bmatrix} \Omega_{Hm} \\ P_{Hm} \end{bmatrix} \tag{45}$$

Substituting equation (35) into equation (45), one obtains

$$\begin{bmatrix} \Omega_{B(m+1)} \\ P_{B(m+1)} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \dfrac{i g_m \Delta \rho_m}{\omega} & 1 \end{bmatrix} \begin{bmatrix} (b_m)_{11} & (b_m)_{12} \\ (b_m)_{21} & (b_m)_{22} \end{bmatrix} \begin{bmatrix} \Omega_{Bm} \\ P_{Bm} \end{bmatrix} \tag{46}$$

For simplicity the following notation is introduced:

$$[M]_m = \begin{bmatrix} 1 & 0 \\ \dfrac{i g_m \Delta \rho_m}{\omega} & 1 \end{bmatrix} \begin{bmatrix} (b_m)_{11} & (b_m)_{12} \\ (b_m)_{21} & (b_m)_{22} \end{bmatrix} \tag{47}$$

For the top layer $m = N$, the following relation holds:

$$\begin{bmatrix} \Omega_{BN} \\ P_{BN} \end{bmatrix} = \begin{bmatrix} (a_N)_{11} & (a_N)_{12} \\ (a_N)_{21} & (a_N)_{22} \end{bmatrix} \begin{bmatrix} 0 \\ A_{N2} \end{bmatrix} \tag{48}$$

Starting from the bottom layer where $m = 1$, one can apply equation (46) to successively eliminate Ω_{Bm} and P_{Bm}, and finally use equation (48) of the top layer to obtain:

$$\begin{bmatrix} (a_N)_{12} \\ (a_N)_{22} \end{bmatrix} A_{N2} = \prod_{N-1} (M_m) \begin{bmatrix} \Omega_{B1} \\ P_{B1} \end{bmatrix} \tag{49}$$

If the earth surface is assumed to be rigid, i.e., $\Omega_{B1} = 0$, then equation (49) can be written as

$$\begin{bmatrix} (a_N)_{12} \\ (a_N)_{22} \end{bmatrix} A_{N2} = \prod_{N-1} (M_m) \begin{bmatrix} 0 \\ P_{B1} \end{bmatrix} \tag{50}$$

By writing the product of [M] matrices as

$$\prod_{N-1} (M_m) = \begin{bmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{bmatrix} \tag{51}$$

and substituting (51) into equation (50), one obtains

$$\frac{(a_N)_{22}}{(a_N)_{12}} - \frac{D_{22}}{D_{12}} = 0 \tag{52}$$

This is the desired frequency dispersion equation of acoustic-gravity waves in a stratified atmosphere.

IV. Numerical Results of Frequency Dispersion Characteristics and Discussion

To apply the frequency dispersion equation (52), the actual atmosphere is approximated by a model consisting of horizontal layers whose parameters are specified or calculated; they include: speed of sound, wind velocity, thickness of each layer, density, gravitational acceleration, and the angle between the direction of sound propagation and the wind direction.

By substituting the specified parameters into the dispersion equation, it reduces to an equation of only the circular frequency ω and the wave number k, which can be solved by numerical methods. In carrying out the solution, a particular value of ω is assumed and a range of values of the wave number k is substituted into equation (52) until the equation is satisfied. For a given value of ω, there may exist several solutions of k. Then, a different value of ω is assumed and the corresponding value of k is determined. By following this procedure, a sequence of ω and k values are obtained which satisfy the equation. The phase velocity V_p and group velocity V_g corresponding to each value of the circular frequency are then determined using the following formulas:

$$V_p = \frac{\omega}{k} \tag{53}$$

$$V_g = \frac{d\omega}{dk} = \frac{V}{1 - \frac{\omega}{V}\frac{dV}{d\omega}} \tag{54}$$

In the calculation an 18-layer atmospheric model is used; the variations in speed of sound (temperature is converted into speed of sound) and wind velocity with altitude are given by Fig. 1 and Fig. 2, respectively. Fig. 1 shows that a minimum temperature exists in the altitude range of 10-30 km; it can be regarded as an approximate model of the atmospheric sound channel. The maximum wind velocity occurs in the altitude range of 10-20 km. When the wind velocity is along the x-axis, i.e., when $\theta = 0$, the wind direction coincides with the direction of sound propagation.

After substituting the corresponding parameters into the frequency dispersion equation, numerical calculations of the dispersion characteristics of phase velocity and group velocity are carried out on the computer for three values of θ: 0, $\pi/2$ and π. The results are shown in Fig. 3. The solid lines in the figure represent phase velocity, where values of θ are correspondingly marked. The calculated dispersion characteristics of group velocity are represented by dash-dot lines. The abscissa denotes period, and the ordinate

denotes phase velocity or group velocity. The figure clearly shows two separate components. The long period portion corresponds to the gravitational component of the acoustic-gravity wave; it has two sets of curves both of which exhibit the feature of the rapid drop in short period velocities. The other component is the acoustic component which has a period of less than few minutes; the short period group velocity approaches the minimum speed of sound of the corresponding sound channel. The Lamb wave is not marked in Fig. 3.

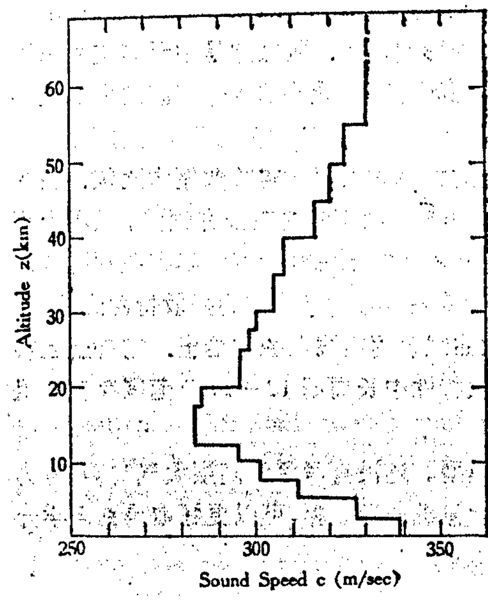

Figure 1. Atmospheric Model Used in Computations

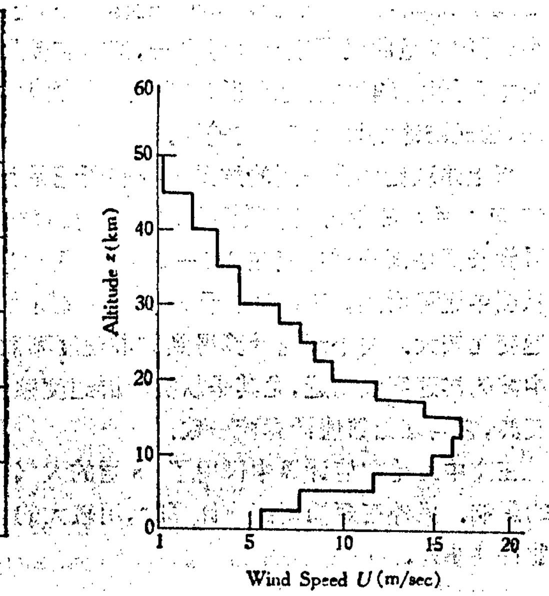

Figure 2. Wind Speed vs Altitude

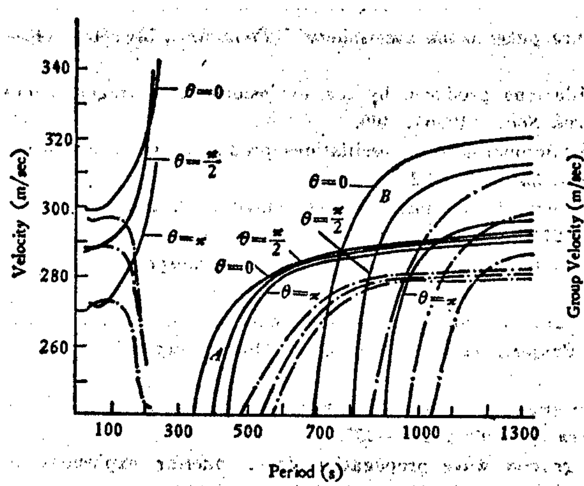

Figure 3. The Phase and Group Dispersion, Theoretical Curves

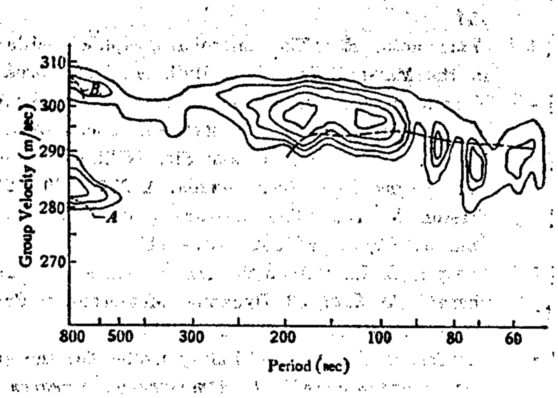

Figure 4. The Observed Dispersion of Nuclear Explosion (recorded in Beijing on 6 January 1957)

The calculations also include high order sinusoids of the acoustic component, but they are not plotted on the figure because of the many repeated roots in the short period portion. It can be seen from the figure that wind has a significant effect on the dispersion characteristics of the group velocity of the acoustic component. For example, the difference in group velocities between downwind and upwind conditions can be as much as 10 percent. In the gravitational component, there is a large difference in dispersion characteristics between the two sets of group velocities. In the set of curves marked as "A," the long period variations in group velocities under three different wind conditions are quite small, and there is very little dispersion. The set of curves marked as "B" have even longer period than the set "A," but they are more affected by wind. Clearly, this is due to the fact that in the wind model used in this article, the maximum value occurs below an altitude of 20 km; consequently it has different effect on gravitational components of different order, which results in differences in the dispersion characteristics of the group velocities.

The results of theoretical calculations presented above have been compared with experimental data of infrasonic waves produced by a nuclear explosion. Fig. 4 shows the three dimensional frequency spectrum of infrasonic waves produced by a Soviet nuclear explosion which was received at Beijing on 6 January 1957. It can be clearly seen from the figure that in the vicinity of 287-290 m/sec and 300-305 m/sec, there are indeed two sets of long period group velocities. In addition, the figure shows the presence of an acoustic component in the short region below 3 minutes; its frequency dispersion characteristics are rather complicated, and vary considerably with wind velocity. The theoretical group velocity curve is also shown in the figure. It approximates well with the group velocity values from experimental data. In particular, the gravitational component of the experimental group velocity dispersion characteristics is in complete agreement with theoretical calculations in the range of periods of 12-20 minutes.

The numerical calculations presented in this article are based on an 18-layer atmospheric model; the effect of high altitude atmosphere on the propagation of acoustic-gravity waves has not been considered. Also, by using a larger computer to carry out short period calculations, improved frequency dispersion curves of the acoustic component can be obtained.

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PRESENT STATUS, FUTURE PROSPECTS OF DOMESTIC ACOUSTICAL INSTRUMENTS

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/Text/

I. Preface

Acoustical instruments (including those to measure sound and vibration) have a wide range of applications in various industries. In the fields of metallurgy, aerospace, power machinery, geology, earthquake research, medicine, etc., and in the dynamic analysis of systems, real-time signal analysis, modelling, verification of systems specifications, instrument calibration, and parameter determination, acoustical instruments are used to anlayze systems response in the time domain or perform spectrum analysis in the frequency domain, and to measure other associated parameters.

In order to meet the urgent needs of the society, China had establised research institutes and factories specialized in the development and production of acoustical instruments. The research and production efforts has had a history of 20 years. Currently, there are more than 30 different kinds of acoustic and vibration measuring instruments being produced domestically, and a preliminary system of product lines and serialized production has been established. Over the past 20 years, the research and production of acoustical instruments in this country have undergone an evolution process.

From the 60's to the early 70's, almost all efforts were devoted to the development of analog instruments. In most designs, various user requirements and serial support for acoustic and vibration measuring systems were taken into consideration. For single unit designs, consideration was given to the various requirements of integrated use of the unit, and a uniform standard of using soft connecting axles was established. More importantly, during this period China had trained a team of qualified technical personnel who were capable of performing independent research and development of acoustical instruments.

During the late 70's, efforts were continued in the development of product lines and serial support of analog instruments; in addition, technical improvements and modifications were also introduced in these instruments. At the same time, a number of technically sophisticated and digital instruments were developed. The acoustical instruments being produced in this country today are essentially attributed to the achievements of these two eras.

Since the 80's, progress has been made in developing new products of acoustical instruments. The main thrust has been to reinforce serial support of existing products, and to improve product quality. At the same time, efforts are being made to apply microprocessor technology to the development of new products of acoustical instruments. The intent is to incorporate fundamental changes in these products so they can catch up and in some respect surpass the products of advanced nations in the near future. It is expected that within the next 2 years, a number of acoustical instruments equipped with LSI devices and software capabilities will appear on the domestic market.

II. Present Status

We shall now introduce the product lines, specifications, and special features of China's main acoustical instrument products, and discuss the methods of operation and the main problems of these products.

1. Product Lines

The acoustic and vibration measuring instruments currently produced in this country may be divided functionally into the following categories:

(1) Signal Generators. There is a wide variety of signal generators. In addition to serving as ordinary signal sources, they can also be used in conjunction with other acoustical instruments to provide a wide range of applications. They are particularly useful in performing acoustic measurements and calibration of electro-acoustical equipment. These instruments have the special feature that they can be manually turned as well as automatically scanned in frequency at different speeds. By connecting them with voltage recorders by means of soft axles, they can be used to perform automatic recording of the frequency characteristics of four-terminal networks and electro-acoustical devices. In order to provide a smooth acoustic field during the measuring process, these instruments are equipped with compression circuits which allow the output to be automatically regulated. There are two different types of frequency scanning: linear and logarithmic. The frequency range is generally between 2 Hz and 200 KHz, with less than 5 percent distortion and less than $\pm$ 0.5 dB in frequency instability. They are also equipped with digital display terminals with six-digit effective accuracy.

(2) Amplifiers. These include power amplifiers (20 W, 50 W etc.), microphone amplifiers, and measuring amplifiers.

The power amplifiers can be used not only in the field of acoustics and vibration but for other applications as well. This is primarily due to its

advanced technical features such as low frequency distortion, wide operating band, and low output noise. In particular, when equipped with an impedance converter, it can be used in conjunction with other acoustical instruments. It is an essential instrument for measuring the frequency response and other parameters of such electro-acoustical instruments as loudspeakers, energy converters, audio transformers, etc.

Microphone amplifiers and measuring amplifiers are amplifiers with unique acoustic features. Special efforts were made to incorporate the following technical features in their design: 1) wide frequency band (2Hz-200 KHz); 2) frequency instability less than $\pm$ 0.5 dB; 3) low noise (approximately 7 μv at wide band); 4) large dynamic range; 5) high gain; 6) consideration was given to solving the problems of matching various sensors; 7) consideration was given to inserting narrow-band filters, and operating in conjunction with other acoustical instruments; 8) consideration was also given to the subjective standard of sound level by adopting the IEC specified A, B, C, D weighting network design.

Amplifiers with the above features can be used with other acoustical instruments to perform frequency analysis and spectrum analysis of weak signals, and in low-noise micro-voltmeters and conventional sound meters.

(3) Filters. There is a rather complete line of bandpass and lowpass filters designed for acoustical measurements. Filter is an essential component in developing a detection system which centers around analog instruments to perform frequency analysis. Therefore, there is large demand for filters in this country. To meet the requirements of acoustic and vibration measurements, special consideration is given to the following issues in the filter design.

Bandpass filter: 1) complete flexibility in the selection of bandwidth: it can be specified either as 3 percent, 23 percent, and continuous turnable frequency, or as 1/3 frequency scale and 1/1 frequency scale; 2) the operating frequency is in the range of 2 Hz to 160 KHz; 3) in addition to linear network, it is also equipped with A, B, C, D weighting network; 4) the filter design takes into consideration its use with other acoustical instruments. Therefore, it is extremely convenient to use the filter in an integrated test system to perform automatic scanning and recording.

Because of the above features in the design of bandpass filter, it can perform a variety of functions such as vibration waveform analysis, narrow-band spectrum analysis of noise (Gaussian or non-Gaussian), spectrum analysis of complex signals, noise classification, and calibration of frequency discrimination systems.

Lowpass filter: There are two kinds of lowpass filters: single channel and dual channel; most of them in use today are dual channel filters. The frequency range generally extends to 20 KHz or 50 KHz, and is divided into 1, 2 and 5 bands. In addition to meeting the conventional technical requirements, lowpass filter has the following features.

1) Instability in the pass band is generally within $\pm$ 0.5 dB, with improved level of $\pm$ 0.3 dB; 2) the rejection band multiple range attenuation can reach 60 dB/oct; 3) the inherent discrepancy between the dual channels is no greater than 2 degrees.

The first feature provides the system with a 1 percent amplitude error. The second and third features are very important for signal analysis both in the time domain and in the frequency domain, particularly the latter. For example, in a FFT digital signal analyzer, the preprocessing section must be equipped with a dual channel lowpass filter to avoid ambiguities. The degree of attentuation at multiple frequency range of the rejection band directly affects the quality of spectral lines on the display. In the analysis of mutual power spectrum, the relative displacement between the channels also introduces errors in the spectral lines.

(4) Voltage Recorder. This type of recorder has certain unique functions. The frequency range of today's product extends to 200 kHz. It can operate in a d. c. mode, and has plotting capability in both polar coordinates and x-y coordinates; it also has several recording speeds with high degree of sensitivity and resolution. In order to better meet the requirements of acoustical measurements, problems concerning the synchronous operation with other acoustic instruments were taken into consideration in the design. The voltage recorder is a critical and fundamental part of acoustical instruments. It is often used in conjunction with many instruments to form an overall detection system. As a recording terminal it has several outstanding features. It can automatically record the parameters related to noise level, reverberation, vibration, surge voltage characteristics, speech dynamics characteristics, speech dynamics characteristics, and broadcast reception. The recorded results can be expressed graphically in the form of a log-arithmic curve versus frequency. In particular, it can display sharp images of the reverberation curve, the frequency scan curve, the spectrum curve, the direction characteristics curve, and the reverberation attenuation curve of the measured system.

(5) Other Test Instruments. At the present time, the following instruments are being commercially produced in this country: 1) Ordinary and precision sound level meters. These meters are being widely used in environmental systems to measure the sound levels of noise fields. Both the linear and weighting type meters are available to perform spectral analyses of the overall sound level of noise fields. 2) Flutter detector. It can measure the flutter of the weighted peak value and linear peak value of recorders, phonographs, and video-recorders. It is very useful for the certification, calibration, and testing of electro-acoustical instruments. The flutter detector is designed according to international IEC and DIN standards, hence the measured flutter parameters are consistent with specifications. 3) Vibration automatic controller. It is used on electromagnetic vibration platform to perform automatic scanning of test objects. When used with a voltage recorder, it can perform automatic recording of vibration levels. Its technical specification approaches that of similar high-quality products manufactured abroad.
(4) Microvoltmeter and auto-range voltmeter. A microvoltmeter is designed

to amplify and indicate very weak signals; it provides a wide voltage scale and covers a wide frequency range with low intput noise and low distortion. If a filter bank is inserted, the voltmeter can also perform frequency and spectrum analyses of weak signals in the microvolt range. Its technical specifications are similar to those of the measuring amplifier. An auto-range voltmeter uses BCD code for range control and automatic range selection. It covers a wide frequency range, and its instability is less than 0.5 dB in the frequency band of 0.5 Hz-500kHz, and as low as 0.2 dB in certain frequency band. It can measure the positive and negative peak values of a complicated waveform as well as its average and effective values. It can be used as a standard amplifier for calibrating other equipment.

Other domestic products such as vibrometer, strike voltmeter, frequency-selection amplifier, and certain analysers and measuring instruments will not be individually discussed here.

2. Basic Test Systems

Because of the wide range of application of acoustical instruments, it is not possible to present examples of each application; we shall briefly illustrate some of the basic test systems.

(1) A text system consisting of measuring amplifier, filter, and voltage recorder is used to perform automatic frequency and spectrum analyses, dynamic testing and automatic recording of sound and vibration. It can perform automatic spectrum analysis of 1/3 frequency scale in the range of 2 Hz-200 kHz.

(2) The frequency characteristics of electro-acoustical devices can be measured by a system which consists of a signal source with dynamic compression, power amplifier (with impedance matching), measuring amplifier, microphone amplifier, voltage recorder, and electro-acoustical devices for calibrating the sound field. Such a system can perform automatic recording of the frequency characteristics of electro-acoustic devices.

(3) A test system consisting of a vibration automatic controller, charge amplifier, voltage recorder, and electromagnetic vibration platform can perform the following functions: scanning of the fixed-acceleration, fixed-velocity, and fixed-displacement vibration of the test object; scanning of the displacement-acceleration, velocity-acceleration, and displacement-velocity vibration of the test object; automatic recording of the vibration level; and determination of the resonnance frequency of the test object.

There are many different types of test systems for meeting various test requirements and objectives. For example, there are systems for testing acoustical materials, for speech analysis, for measuring the sound level, flutter, vibration, surge, and for measuring the water sound.

III. Future Prospects

At present, most of the commercial acoustic and vibration measuring instruments are analog devices. After many years of dedicated efforts, a preliminary system of product line and serialization has been established. Continued efforts are being made in the areas of product serialization and reform of analog instruments.

However, due to the inherent deficiency of analog instruments, we must follow a new approach, which is to apply microprocessor technology in the design of acoustical instruments. By using LSI devices, the design and structure of the instrument hardware can be simplified, and system tuning and testing can be facilitated. Also, by implementing software capabilities, the functions of acoustical instruments can be greatly expanded.

There are many different types of digital signal analyzers available on the foreign market. The ones that have been imported to this country include the following: the 5420, 5421, made by the Hewlett-Packard Company of the United States; the 2031, 2033 made by the B. K. Company of Denmark; the TR-9305 made by Takeda Riken of Japan, the 7T-80 made by Sanei of Japan, and products of Ono Sokki of Japan. Many of the digital signal analyzers from abroad use the 2900 series chips, and a hardware system using the 2901 or 1903 as its core. They use microprocessor design to accomplish multiple system functions. These products are highly regarded by the users in terms of their efficiency, performance, and precision.

In this country, design effort is under way to develop a first-generation digital signal analyzer which is based on the method of FFT and uses the 2900 series chips and microprocessor design. In addition, small digital signal analyzer can be constructed by using Z-80 hardware and developing compiler-language software to meet user requirements. This type of instruments can perform the following functions: power spectrum, Fourier spectrum (amplitude and phase), auto-correlation function, cross-correlation function, mutual power spectrum, time waveform analysis, circular integral, transfer function, probability density function, vibration velocity and acceleration.

The main features of a digital signal analyzer are as follows:

1. The pre-processing of signal prior to the A/D converter is completely program-controlled; it also has post-processing capability and the capability of capturing the trigger of pulsed signals. 2. It has both macro-instruction and micro-instruction systems and hardware multiplication device to provide high degree of flexibility in system performance and high computational speed. 3. It uses ZOOM technology to facilitate the analysis of fine structures of spectrum. 4. Its large storage capacity allows comparison between standard samples and the detected signal, and provides dual-picture displays of the detected signal and processed signal. 5. Its panel arrangement is flexible and easy to use. Each function is self-locking. By connecting to CRT scopes, it can provide the capability of interactive multi-picture displays. 6. In addition to graphical displays, the CRT scope can

also display the absolute coordinates and related parameters (test inventory). 7. It uses the IEEE-488 standard to provide parallel interfaces for peripheral equipment.

Improvements of acoustical instruments can also be made in the time domain by using microprocessor technology. It may be convenient to divide a test system into a number of modularly connected instruments. By using a standard overall circuit interface, the modular instruments can be used in conjunction. An automated test system can thus be developed whose operation is controlled by software. The concept of modular structure and program-controlled operation have already been implemented in automated test instruments which are available on the foreign market.

Automatic control system can play an effective role in the field of acoustic instruments. However, the following design issues must be addressed: 1. Process control of the analog pre-processor and the post-processor; process control is required for pre-amplifier, the dula-channel lowpass filter, the amplifier, and the power amplifier; they must also be under the control of the IEEE-488 standard circuit. 2. Implementation of A/D and S/H. 3. Miniaturization of the frequency synthesizer, the dual-channel phase meter, the narrow-band filter, the frequency scanner, and the full-screen CRT with three-dimensional display.

In order to meet the demands of the four modernizations on acoustical instruments, we, as developers, must devote our maximum effort.

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END